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(54) **ACTIVE ELECTRIC ACCUMULATOR**

(75) Inventors: **Edward W. Mellet**, Rochester Hills, MI (US); **Clinton E. Carey**, Highland, MI (US); **Carlos E. Marin**, Oxford, MI (US)

(73) Assignee: **GM Global Technology Operations LLC**, Detroit, MI (US)

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F04B 17/03 (2006.01)

(52) **U.S. Cl.** **417/417**; 417/415; 417/540

(58) **Field of Classification Search** 417/540, 417/415, 417, 419–420

See application file for complete search history.

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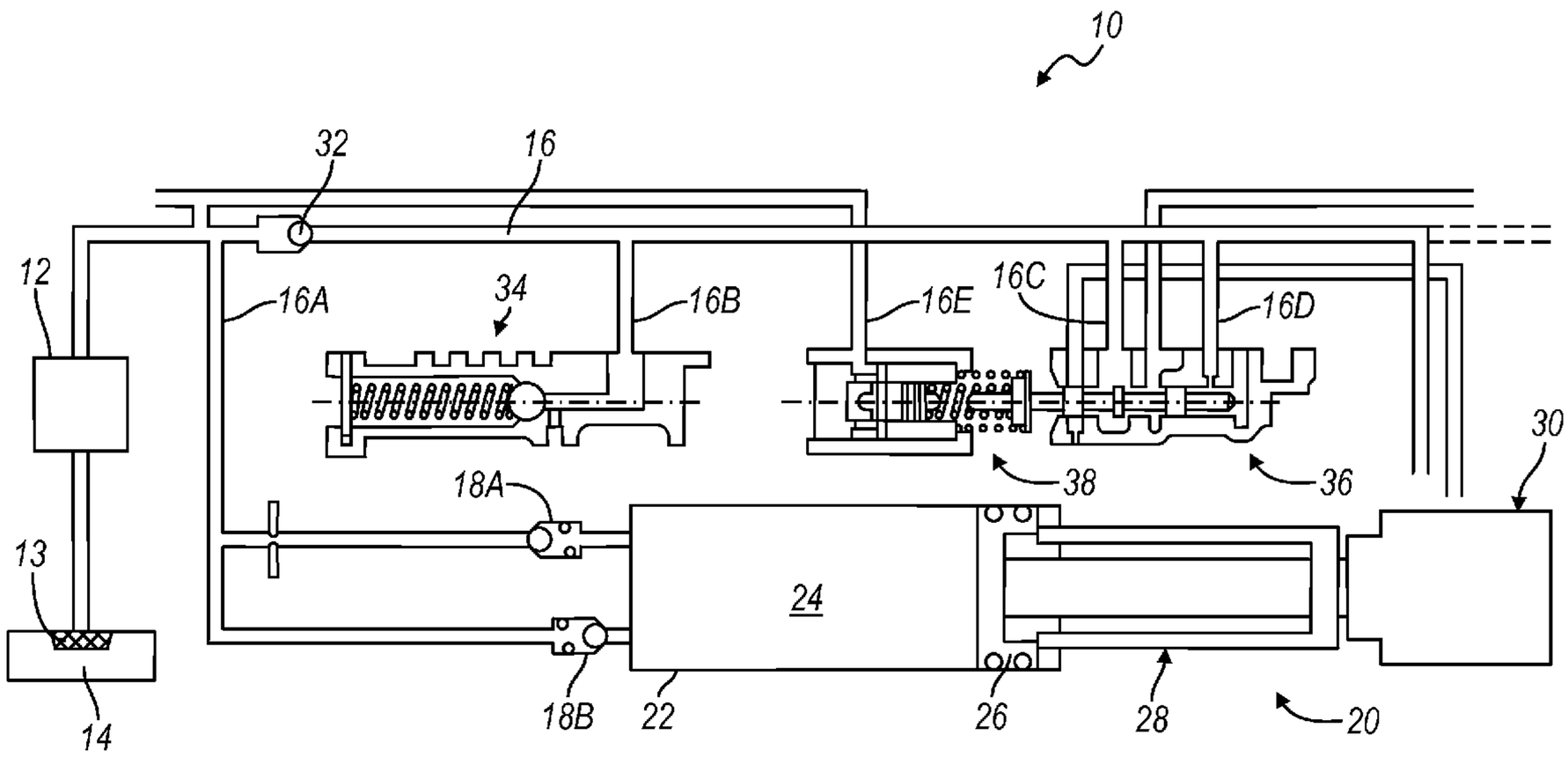
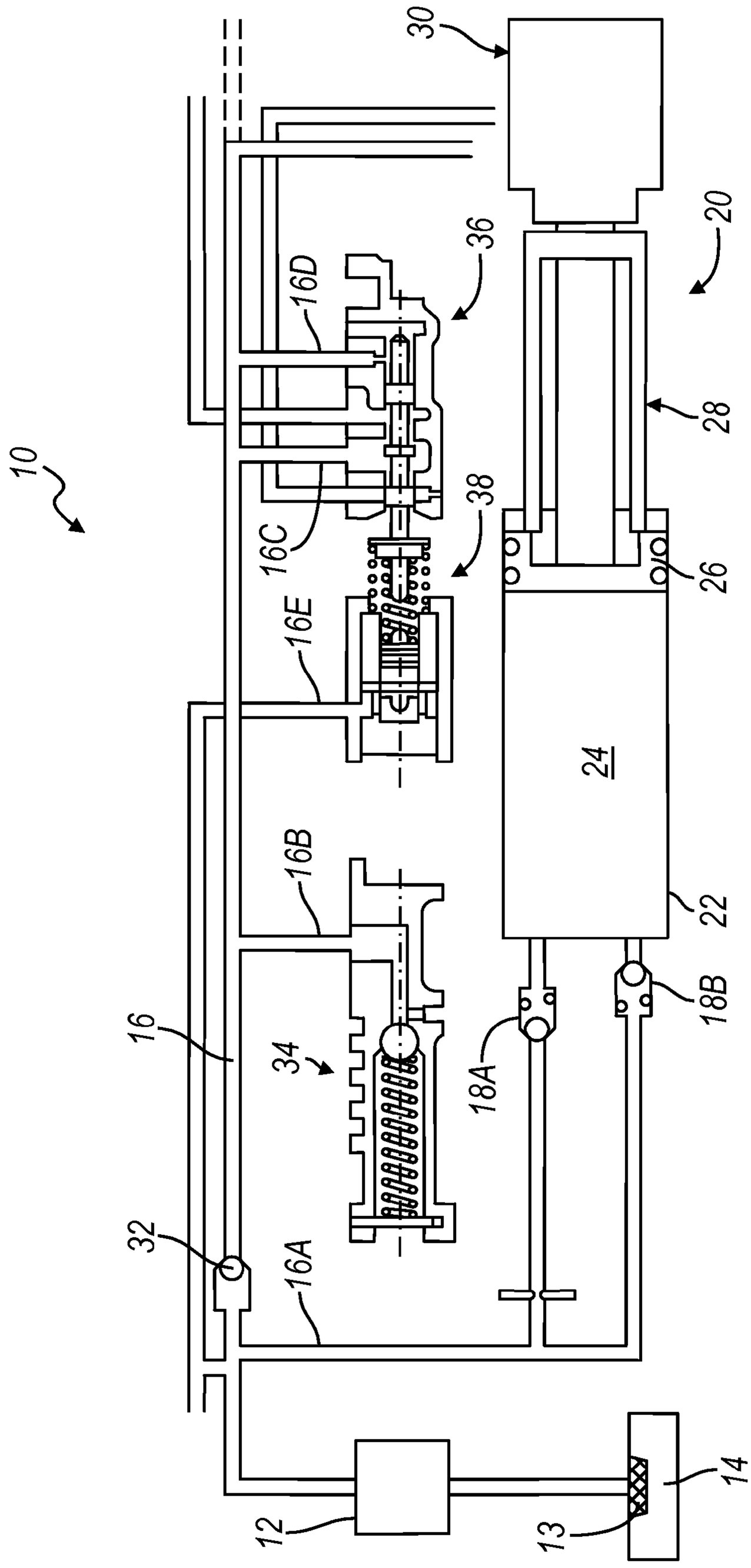
Primary Examiner — Karabi Guhary

(57) **ABSTRACT**

The present invention provides an active, electrically powered hydraulic fluid accumulator. The accumulator includes an electric motor having its output coupled to a mechanical rotation to linear translation transducer such as a lead screw, ball spline or similar device. The output of the mechanical transducer is coupled to a piston disposed within an accumulator cylinder. The accumulator cylinder preferably communicates with a pair of inlet and outlet check valves disposed in hydraulic supply and feed lines from the system pump or sump and to the system, respectively.

15 Claims, 3 Drawing Sheets

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16D
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16C
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14

FIG. 1

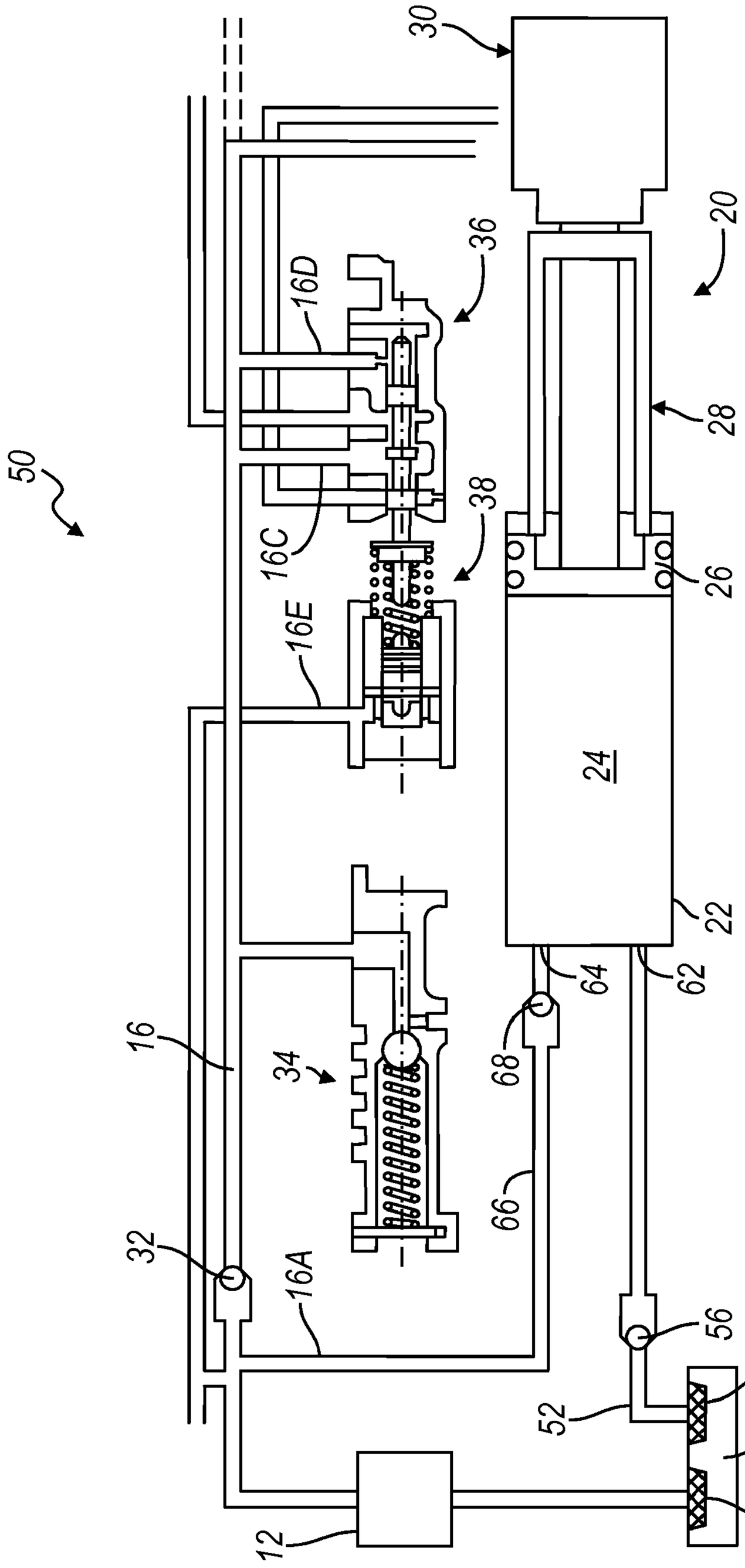
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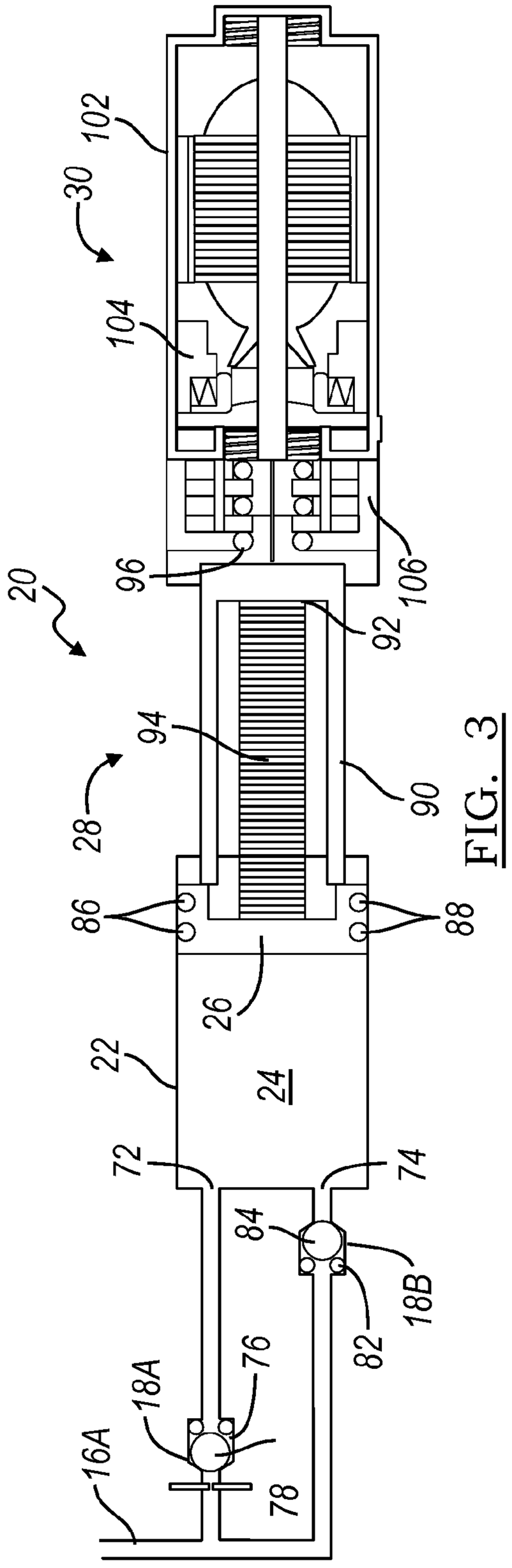
FIG. 2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30
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96
106
92
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22
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72
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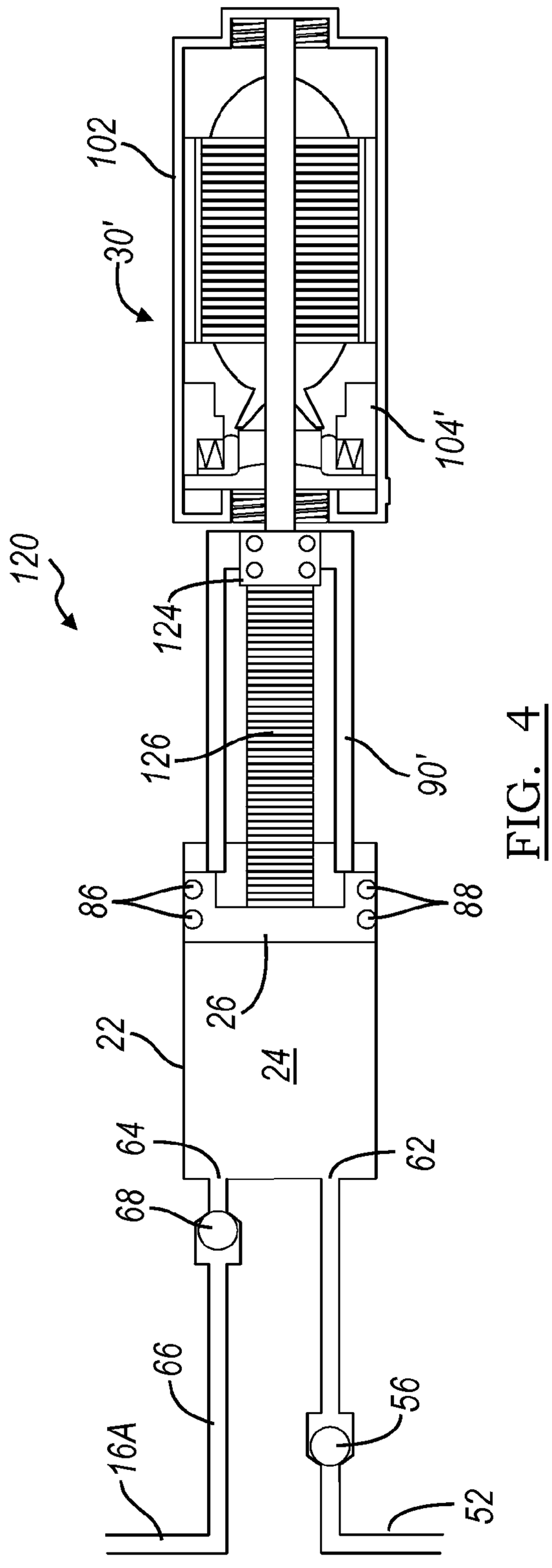
84
18B
82
76
18A
16A
78

FIG. 3


102
30'
104'
120
124
126
90'
86
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16A
52

FIG. 4

ACTIVE ELECTRIC ACCUMULATOR

FIELD

The present disclosure relates to an accumulator for a hydraulic system and more particularly to an active accumulator having an electric motor for a hydraulic control system.

BACKGROUND

The statements in this section merely provide background information related to the present disclosure and may or may not constitute prior art.

Accumulators are common components in hydraulic operating and control systems. They are utilized to store a quantity of hydraulic fluid or oil under pressure so that during relatively brief periods of fluid consumption that either exceed the supply capacity of the system pump or during periods that the pump is not operating, there continues to be a sufficient supply of pressurized hydraulic fluid so that operating pressure and flow do not drop below a required minimums.

Such devices may be characterized as passive devices and typically take the form of a cylinder having a combined inlet and outlet port and a piston that is biased toward the inlet/outlet port by a compression spring, a gas on the side of the piston opposite the inlet/outlet port, latching solenoids or other means.

There exist certain problems associated with such devices which are the result of their passive operation. First of all, they generally do not accumulate fluid and thus provide their intended function until the system pump has operated long enough to generate a sufficiently high pressure and provide a quantum of excess fluid which is then directed to and stored in the accumulator. Thus, at system start-up and for a short period thereafter, an accumulator not only typically does not provide the function for which it is intended but will also actually consume pressurized fluid until it is charged thereby effectively lengthening the startup cycle of the system. Moreover, if the charge time of the accumulator is greater than the duration on an operating cycle, little or no operating benefit will be provided by the accumulator. Thus, both during system start-ups and short cycles of operation, a passive accumulator likely will not provide its intended function.

Furthermore, since an accumulator is passive, it cannot create a pressure any higher than that generated by the system pump. If the pump is failing or the system is undergoing a cold start and thus building pressure slowly, not only does the accumulator once again not provide its intended function but it is also unable to achieve any active corrective or compensatory action. The present invention is directed to overcoming these and other shortcomings of conventional, passive fluid accumulators.

SUMMARY

The present invention provides an active, electrically powered hydraulic fluid accumulator. The accumulator includes a bidirectional electric motor having its output coupled to a mechanical rotation to linear translation transducer such as a lead screw, ball spline or similar device. The output of the transducer is coupled to a piston disposed within an accumulator cylinder. The accumulator cylinder preferably includes a pair of inlet and outlet check valves communicating with hydraulic supply and feed lines from the system pump or sump and to the system, respectively. The active electric accumulator of the present invention has wide application in hydraulic systems such as hydraulic control systems and hydraulic control systems for motor vehicle automatic transmissions.

Thus it is an object of the present invention to provide an active hydraulic fluid accumulator for use in hydraulic systems.

It is a further object of the present invention to provide an active hydraulic fluid accumulator for use in hydraulic control systems.

It is a still further object of the present invention to provide an active hydraulic fluid accumulator having an electric motor for use in hydraulic systems.

It is a still further object of the present invention to provide an active hydraulic fluid accumulator having a mechanical rotation to translation transducer for use in hydraulic systems.

It is a still further object of the present invention to provide an active hydraulic fluid accumulator having an electric motor and a mechanical rotation to translation transducer for use in hydraulic systems.

It is a still further object of the present invention to provide an active hydraulic fluid accumulator having an electric motor and a mechanical rotation to translation transducer for use in hydraulic control systems.

Further objects, advantages and areas of applicability will become apparent from the description provided herein. It should be understood that the description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present disclosure in any way.

FIG. **1** is a schematic diagram of an active electric accumulator according to the present invention in a first hydraulic fluid system application;

FIG. **2** is a schematic diagram of an active electric accumulator according to the present invention in a second hydraulic fluid system application;

FIG. **3** is a full sectional view of a first embodiment of an active electric accumulator according to the present invention; and

FIG. **4** is a full sectional view of a second embodiment of an active electric accumulator according to the present invention.

DETAILED DESCRIPTION

The following description is merely exemplary in nature and is not intended to limit the present disclosure, application, or uses.

With reference to FIG. **1**, a portion of a hydraulic system incorporating the present invention is illustrated and generally designated by the reference number **10**. The hydraulic system **10** includes a main hydraulic pump **12** which draws hydraulic fluid through a filter **13** from a sump **14**. The hydraulic pump **12** may be a gear pump, a gerotor pump or other, preferably positive displacement, pump typically driven by a prime mover (not illustrated) such as an internal combustion gas or Diesel engine or hybrid or electric power plant.

A main branching supply line **16** leads from the output of the main hydraulic pump **12** to a first line **16**A which bifurcates and includes a pair of oppositely arranged spring biased check valves **18**A and **18**B. The first line **16**A functions as a supply and return line to an active electric accumulator **20**.

The pair of spring biased check valves **18**A and **18**B inhibit flow into and out of the active accumulator **20** until predetermined pressure differentials are achieved across them. The active electric accumulator **20** includes a cylindrical housing **22** defining a cylinder **24** which receives a piston **26**. The piston **26** is coupled to and driven by a mechanical rotation to linear translation transducer assembly **28** which, in turn, is driven by an electric drive assembly **30**. These components of the active electric accumulator **20** will be more fully described subsequently.

The main supply line **16** includes a first check valve **32** which allows fluid flow from the hydraulic pump **12** and the active accumulator **20** to downstream lines and components of the hydraulic system **10** such as a second line **16**B which communicates with a pressure relief valve **34** and other components but inhibits return or reverse flow from such components to the hydraulic pump **12** and active accumulator **20**. The main branching supply line **16** also includes, solely by way of example and illustration, a third line **16**C and a fourth line **16**D which supply hydraulic fluid to certain ports of a hydraulic pressure regulator or spool valve **36** as well as an additional branch **16**E. The hydraulic pressure regulator or spool valve **36** is controlled by an actuator **38**.

Referring now to FIG. **2**, a portion of a second hydraulic system incorporating the present invention is illustrated and generally designated by the reference number **50**. The second hydraulic system **50** includes the hydraulic pump **12** which is, again, preferably a positive displacement type which draws hydraulic fluid through the filter **13** from the sump **14**. The hydraulic pump **12** is typically driven by a prime mover (not illustrated). The second hydraulic system **50** also includes the main branching supply line **16**, the active accumulator **20**, the first check valve **32**, and, solely by way of example and illustration, the hydraulic lines **16**B, **16**C, **16**D, and **16**E, the pressure relief valve **34**, the hydraulic pressure regulator or spool valve **36** and the actuator **38**.

In the second hydraulic system **50**, an accumulator supply line **52**, preferably including a filter **54**, leads from the sump **14** to an intake check valve **56** which is arranged in the accumulator supply line **52** to permit hydraulic fluid flow from the sump **14** but inhibit return flow to it. The accumulator supply line **52** communicates with and terminates at an inlet port **62** in the housing **22** of the active accumulator **20** which communicates with the cylinder **24**. An outlet port **64** in the housing **22** communicates with a system supply line **66** having an outflow check valve **68** which is arranged to permit hydraulic fluid flow from the cylinder **24** to the main branching supply line **16** but inhibit return flow to it. The active accumulator **20** also includes the cylinder **24**, the piston **26**, the mechanical rotation to linear translation transducer assembly **28** and the electric drive assembly **30**.

In the second hydraulic system **50**, the active electric accumulator **20** is arranged in parallel with the primary source of pressurized hydraulic fluid, the hydraulic pump **12**, and thus may function as a second, essentially independent, though limited, source of pressurized hydraulic fluid. Since the active electric accumulator **20** can operate independently of the hydraulic pump **12**, it is preferably disposed within the sump **14**, with its inlet below the nominal fluid level, such that it has a ready supply of hydraulic fluid wholly independent of the operation and supply from the pump **12**.

Referring now to FIG. **3**, a first embodiment of the active electric accumulator **20** is illustrated. As noted, the active electric accumulator **20** includes the preferably cylindrical housing **22** which defines a first, inlet port or passageway **72** and a second, outlet port or passageway **74**. If desired, the first and second ports **72** and **74** may be combined into a single port or passageway. The first check valve **18**A communicates with the first, inlet port **72** and includes a compression spring **76** which biases the ball check **78** to a closed position until fluid pressure against the ball check **78** overcomes the force of the spring **76** at which time hydraulic fluid flows through the first check valve **18**A and through the first, inlet port **72**, into the cylinder **24**. The second check valve **18**B communicates with the second, outlet port **74** and includes a compression spring **82** which biases the ball check **84** to a closed position until fluid pressure against the ball check **84** overcomes the force of the spring **82** at which time hydraulic fluid flows out through the second, outlet port **74** and the second check valve **18**B.

The cylindrical housing **22** defines the smooth walled cylinder **24** which slidably receives the piston **26**. The piston **26** defines a pair of circumferential grooves or channels **86** which each receives and retains an O-ring seal **88**. The piston **26** is coupled to an intermediate, elongate tubular member **90** which defines a portion of the rotation to translation transducer assembly **28**. The tubular member **90** includes a coaxially disposed opening having internal or female threads **92**. The threads **92** are engaged by a complementarily threaded rod or leadscrew **94** which is bi-directionally rotated by an output member **96** of the electric drive assembly **30**. It will be appreciated that other rotation to translation mechanical transducers, for example, ball splines, coil springs, cams and the like, may be substituted for the complementarily threaded members described, all of which are deemed to be within the scope and teaching of the present invention.

In the first embodiment of the active electric accumulator **20**, the electric drive assembly **30** includes a bidirectional, fractional horsepower electric motor **102** having an output shaft **104** which is coupled to and drives an input member of a planetary gear speed reduction assembly **106** which drives the output member **96**. The output member **96** may be, for example, a shaft or a planet gear carrier which is coupled to the threaded shaft or leadscrew **94** by splines or other suitable connection. The electric motor **102** may by in fluid communication with the cylinder **24** in which case the hydraulic fluid acts as a coolant and heat transfer medium for the motor **102** or it may be permanently sealed. Additionally, the electric motor **102** may be disposed within the cylindrical housing **22** or it may be externally mounted and attached thereto.

With regard to the planetary assembly **106**, although other types of speed reduction assemblies may readily be utilized, planetary gear assemblies are preferred because of their concentric configuration and the ease with which a multiple stage planetary gear assembly may be designed and packaged. Depending upon the desired response speed versus pressure characteristics of the active accumulator **20**, a single or a double planetary gear train may be incorporated into the speed reduction assembly **106**.

Referring now to FIG. **4**, a second embodiment of an active electric accumulator according to the present invention is illustrated and generally designated by the reference number **120**. The second embodiment active electric accumulator **120** incorporates the same cylindrical housing **22** which defines the same cylinder **24** in which the same piston **26** resides and bi-directionally translates. The piston **26** includes the two circumferential grooves or channels **86** which each receive an O-ring seal **88**. The piston **26** is coupled to an elongate tubular member **90'** having a recirculating ball nut or ball spline assembly **124** at its end opposite the piston **26**. The recirculating ball nut or ball spline assembly **124** receives a threaded shaft or leadscrew **126** having male or external threads complementary to the configuration of the recirculating ball nut assembly **124**. Bi-directional rotation of the shaft or lead-

screw **126** bi-directionally translates the piston **26** within the cylinder **24**. The threaded shaft or leadscrew **126** is coupled to and bi-directionally rotated by an output shaft **104'** of the bi-directional, fractional horsepower electric motor **102**.

The direct drive configuration of the second embodiment active electric accumulator **120** provides relatively faster response and fluid flows than the reduced speed drive of the first embodiment active electric accumulator **20** which is capable of operating at and providing relatively higher fluid pressures. Thus, whether a single or multiple stage gear speed reduction assembly **106** such as illustrated in FIG. **3** or a direct drive assembly such as illustrated in FIG. **4** is utilized in an active electric fluid accumulator according to the present invention is dependent upon system hydraulic fluid flow and pressure requirements and operating parameters as well as the power output of the electric motor **102**.

It should be appreciated that although the first embodiment active electric accumulator **20** has been generally illustrated and described in FIG. **3** in conjunction with the hydraulic system **10** and that the second embodiment active electric accumulator **120** has been generally illustrated and described in FIG. **4** in conjunction with the hydraulic system **50**, either active accumulator is suitable and appropriate for use in either system. Likewise, although the planetary gear speed reduction assembly **106** in FIG. **3** has been described in conjunction with the threads **90** in the tubular member **90** whereas the direct drive configuration of FIG. **4** has been described in conjunction with the recirculating ball nut or ball spline assembly **124**, either mechanical transducer assembly **28** may be utilized with either electric drive assembly **30**.

It should also be appreciated that the active electric accumulators **20** and **120** according to the present invention provide numerous advantages and benefits relative to conventional, passive accumulators. First of all, the accumulators **20** and **120** can be fully charged by actuation of the electric motor **102**. Thus, even before system start-up, the accumulator may be fully charged and ready to provide its intended function. A second benefit, also related to the independent operation of the electric motor **102** is that the accumulators **20** and **120** can be filled or charged without or independent of the establishment of system fluid pressure or flow. Furthermore, by modulating the speed of the electric motor **102**, the rate of re-fill or re-charge and discharge may be controlled. Finally, the accumulators **20** and **120** can be utilized as low flow and pressure pumps, supplementing or substituting for the main system hydraulic pump **12** during brief periods of high system flow demand or other transient conditions.

The description of the invention is merely exemplary in nature and variations that do not depart from the gist of the invention are intended to be within the scope of the invention. Such variations are not to be regarded as a departure from the spirit and scope of the invention.

What is claimed is:

1. An active accumulator for a hydraulic system comprising, in combination,

a housing defining a cylinder and including an inlet port and an outlet port communicating with said cylinder, a piston slidably disposed within said cylinder,

a first check valve in fluid communication with said inlet port and a second check valve in fluid communication with said outlet port,

a hydraulic fluid sump and a line communicating between said sump and said first check valve,

an electric motor assembly having a bi-directionally rotating output,

a planetary gear set having an input member and an output member, wherein said input member is connected to said bi-directionally rotating output of the electric motor assembly, and

means operably disposed between said output member of said planetary gear set and said piston for converting said rotating output to linear translation.

2. The active accumulator of claim **1** wherein said electric motor assembly includes a bi-directional electric motor.

3. The active accumulator of claim **1** wherein said means for converting includes a threaded shaft and a thread engaging member on said shaft.

4. The active accumulator of claim **1** wherein said piston includes two circumferential grooves in each of which is disposed an o-ring seal.

5. The active accumulator of claim **1** wherein said electric motor assembly is coupled to said input of the planetary gear set and the bi-directionally rotating output is a planet gear carrier of the planetary gear set.

6. The active accumulator of claim **1** wherein said planetary gear set is a double planetary gear train.

7. An active electric accumulator for a hydraulic system comprising, in combination,

a housing defining a cylinder and a first fluid passageway through said housing into said cylinder,

a first check valve in fluid communication with said first fluid passageway for allowing fluid flow into said cylinder,

a second check valve in fluid communication with said first fluid passageway for allowing fluid flow out of said cylinder,

a hydraulic fluid sump and a hydraulic line communicating between said sump and said first check valve,

a piston disposed for bi-directional translation within said cylinder,

an electric motor assembly having a bi-directionally rotating output,

a planetary gear set having an input member and an output member, wherein said input member is connected to said bi-directionally rotating output of the electric motor assembly, and

means mechanically coupling said output member of said planetary gear set and said piston for changing bi-directional rotation into bi-directional translation.

8. The active electric accumulator of claim **7** further including a second fluid passageway through said housing into said cylinder, a first check valve in fluid communication with said first fluid passageway for allowing fluid flow into said cylinder and a second check valve in fluid communication with said second fluid passageway for allowing fluid flow out of said cylinder.

9. The active electric accumulator of claim **7** wherein said electric motor assembly includes a bi-directional electric motor.

10. The active electric accumulator of claim **7** wherein said means for changing includes a ball screw assembly.

11. The active electric accumulator of claim **7** wherein said piston includes two circumferential grooves in each of which is disposed an o-ring seal.

12. The active electric accumulator of claim **7** wherein said electric motor assembly is coupled to said input of the planetary gear set and the bi-directionally rotating output is a planet gear carrier of the planetary gear set.

13. The active electric accumulator of claim **7** wherein said planetary gear set is a double planetary gear train.

14. An active electric accumulator for a hydraulic system comprising, in combination,

a housing defining a cylinder and a first fluid opening through said housing into said cylinder,

a piston disposed within said cylinder for bi-directional translation toward and away from said opening,

a first check valve in fluid communication with said fluid opening for allowing fluid flow into said cylinder,

a second check valve in fluid communication with said fluid passageway for allowing fluid flow out of said cylinder,

a fluid sump and wherein said first check valve is in fluid communication with said fluid sump,

an electric motor assembly having a bi-directionally rotating output, and

a planetary gear set having an input member and an output member, wherein said input member is connected to said bi-directionally rotating output of the electric motor assembly, and

a threaded shaft coupled to said output member of said planetary gear set and a complementary member disposed about said shaft and coupled to said piston,

whereby bi-directional rotation of said shaft bi-directionally translates said piston.

15. The active electric accumulator of claim **14** further including a second opening in said housing and wherein one of said check valves communicates through one of said openings with said cylinder and another of said check valves communicates through another of said openings with said cylinder.

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